Mechanical Automatic Lift-Gate Mechanism for Controlled Release of Walleye into Lake Winnipegosis

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MECHANICAL AUTOMATIC LIFT-GATE MECHANISM FOR CONTROLLED RELEASE OF WALLEYE INTO LAKE WINNIPEGOSIS

by

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TABLE OF CONTENTS

Page

ABSTRACT/RESUME iv

INTRODUCTION 1

EARLIER TECHNIQUE 1

DIFFICULTIES AND PROBLEMS 1

DESIGN PHILOSOPHY 1

DESIGN CONSIDERATIONS 1
Power supply 1
Operating mechanism 2
Control system 2
Safety and overload features 2

TESTING AND FIELD INSTALLATION 3

RESULTS 3

FUTURE MODIFICATIONS AND TESTS 3

ACKNOWLEDGMENTS 3

REFERENCES 3

LIST OF FIGURES

Figure

1 Manually operated control gate 4

2 Walleye migration pattern 5

3 Battery power pack in waterproof box 6

4 Modified gate details 7

5 Control system block diagram 8

6 Pacheta Lake unit (normal operating mode) 9

7 Pacheta Lake unit (housing lifted) 9

8 Pacheta Lake unit (showing controls and worm gear) 10

ABSTRACT

Scott, K.R. 1982. Mechanical automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can. Manuscr. Rep. Fish. Aquat. Sci. 1675: iv + 10 p.

A walleye rearing and stocking program on Lake Winnipegosis, Manitoba involved the use of manual culvert lift-gates to facilitate fish releases. Fingerling walleye were planted in several shallow natural or artificial ponds in the spring, reared over the summer in a predator-free environment and released in the fall after attaining a more viable size.

A battery-operated system controlled by a time clock was designed to operate the gates at times corresponding to the natural migration pattern of the fish and allow unattended operation at remote sites for periods up to 42 days. Pond water levels were thus maintained and manpower requirements drastically reduced. The worm gear drive unit was operated by a reversible 1 hp direct current motor, powered by two heavy-duty lead-acid tractor batteries. Cost of converting a manual gate to automatic operations was $1108.00.

Key words: automated dams; culvert; pond culture; rearing; fingerlings, walleye.

RESUME

Scott, K.R. 1982. Mechanical automatic lift-gate mechanism for controlled release of walleye into Lake Winnipegosis. Can. Manuscr. Rep. Fish. Aquat. Sci. 1675: iv + 10 p.

Dans le cadre d'un programme d'élevage et d'ensemencement de dorés mis sur pied au Lake Winnipegosis (Manitoba), on a installé des dalots munis de portes relevables à la main pour faciliter la libération des poissons. Au printemps, plusieurs étangs naturels ou artificiels furent ensemencés d'alevins de dorés. On laissa les alevins croître dans ce milieu libre de tout prédateur jusqu'à ce qu'on les libère en automne, leur plus grande taille améliorant leurs chances de survivre.

Un dispositif à piles commandé par une minuterie fut conçu pour actionner les portes au moment des mouvements migratoires naturels des poissons. Ce dispositif pouvait assurer le fonctionnement automatique des portes installées dans les lieux éloignés pendant une durée maximum de 42 jours. On a donc pu maintenir le niveau d'eau dans les étangs tout en réduisant considérablement l'effectif nécessaire à cette tâche. Chaque dispositif comprend un engrenage à vis sans fin qu'entraîne un moteur de 1 ch, réversible, à courant continu et alimenté par deux batteries à plomb grande capacité pour tracteurs. La mécanisation d'une porte coûte $1 108.

Mots-clés: barrages automatisés; dalots; culture en étang; élevage; alevins; doré.

INTRODUCTION

The Province of Manitoba is engaged in an extensive walleye rearing and stocking program on Lake Winnipegosis. The procedure involves planting fingerlings early in the spring in eleven different small lakes or ponds at various locations around Lake Winnipegosis and releasing them when the fish reach a survivable size in the late fall.

EARLIER TECHNIQUE

The original method of doing this is to merely dam up the outlet of the small lakes with an earthen dike (or berm) until it is time to release the fish. This serves two purposes. Firstly, the fingerlings are protected from predators entering from Lake Winnipegosis during their first year. Secondly, water levels are maintained sufficiently high to permit successful migration into Lake Winnipegosis. Since the ponds are only about seven feet deep, winterkill eliminates overwintering predators remaining in the rearing pond. At the time of release, the earthen dike is removed and the fish are free to migrate into Lake Winnipegosis in search of better food supplies.

DIFFICULTIES AND PROBLEMS

Most of the pond sites were located in inaccessible areas not served by roads and could only be reached over winter roads or by aircraft, boat or four-wheel drive vehicle, making the whole operation rather costly. To help solve the problem, seven of the eleven locations were fitted with outflow channel culverts ranging in size from 24 to 48 inches diameter and each was equipped with a lift gate manually operated by means of a hand wheel (Fig. 1). These gates facilitated fish releases but, due to the difficulty of reaching the sites, the gates would often be left open once releases started. This resulted in rapidly lowered water levels which prevented natural migration, necessitating manual transfer of the stranded fish into Lake Winnipegosis.

DESIGN PHILOSOPHY

As a result of a meeting in 1976 of a Task Force investigating areas of federal-provincial cooperation, it was suggested that the Industry Services Section of the Department of Fisheries and Oceans undertake to design a system to automatically raise and lower the control gates at selected times. The first suggestion was to activate the gates either by radio, direct from Dauphin, or from an aircraft flying over the site. A preliminary estimate for this system was $1000 to modify the mechanical gate lifting mechanism and provide a suitable power pack for one lift gate unit, plus an additional $2400 for the radio controlled feature. This radio controlled feature was considered too expensive, so an alternate system was sought.

Previous studies (T. Smith, personal communication) indicated that walleye have a decided preference to migrate only during a few hours of each day. The majority of the fish will pass through an open control gate between the hours of 4:00 p.m. and midnight (Fig. 2). This suggested that a simple time clock could be used to open the gate at 4:00 p.m. and close it at midnight. Estimated cost to equip a 24 inch gate with this system was $1100 which would eliminate the expensive and potentially unreliable radio link and make the system completely self-contained. This was the final approach decided upon and the design proceeded on this basis.

DESIGN CONSIDERATIONS

POWER SUPPLY

Since there is no electrical service at any of the sites, a suitable battery pack had to be selected. Automotive type wet storage batteries were chosen for the power supply, because of their low cost, ready availability and good reliability. Following discussions with battery manufacturers, it was decided that due to the fairly fast charge loss rate of standard 12 V batteries the best choice was 6 V golf cart batteries since they are designed to operate for long periods between recharges. To reduce operating current and cable size, an operating voltage of 24 volts D.C. was selected. The number of batteries needed was calculated using the following specifications and assumptions:

1. Seasonal operating time = 180 d.
2. Time to raise gate 30 inches is 2 min, therefore lifting rate = 30/2 = 15 in/min.
3. Daily operating time (2 min up and 2 min down) = 4/60 = 0.0666 h.
4. Shaft screw thread - Acme 4 threads per inch or 4 revolutions per inch travel (RPI).
5. Torque on hand operating wheel = 50 ft-lb (50 lb turning couple at 1 ft diameter).
6. Battery capacity = 250 Ah at 6 V.

Using the above information we get:

Revolutions per minute (RPM)
= Lifting rate (in/min) x RPI
= 15 x 4 = 60 RPM

$$\text{Horsepower} = \frac{2\pi \times T \times RPM}{33\,000}$$

$$= \frac{2\pi \times 50 \times 60}{33\,000} = 0.571 \text{ hp}$$

Assuming a motor and power train efficiency of 80%, total wattage required from the batteries
= (0.571 x 746)/0.8 = 532 W

At 24 V (Four - 6V batteries in series)
Amperes = 532/24 = 22.2

Seasonal operating time (h)
= Daily operating time (h/day)
x days per season
= 0.0666 x 180 = 12 h

Therefore Ampere hours (Ah) required
= 22.2 x 12 = 266 Ah

Continuous current required for the integrated currents (IC's) on the control card = 0.020 A

Therefore card ampere hours (Ah)
= 0.02 x 24 x 180 = 86 Ah

Total ampere hours = 266 + 86 = 352 Ah

Since four batteries in series provide only 250 Ah at 24 V, an additional string of four batteries was connected in parallel with the first four giving an adequate safety margin for motor starting surges. This assembly was then placed in a waterproof ABS plastic box. (Fig. 3A) The final operating regime of the system, however, was only 42 d, therefore the original 8 x 6 V power pack was replaced with the 2 x 12 V pack shown in Fig. 3B. In order to avoid damage or theft, the power pack was buried underground, near the lift gate. Power was brought to the operating motor by a buried waterproof cable and installed in a heavy metal conduit, welded to the lift-gate angle iron support.

OPERATING MECHANISM

Several steps were required to convert the gate from manual to automatic operation. Firstly, the original steel threaded shaft was replaced with a stainless steel shaft in order to avoid rusting and jamming, problems which had plagued the manual system. Next, all of the supporting 3/16 inch angle iron frame was replaced with 5/16 inch angle both for added strength and for a better fit with the gate guide slots. The original manual turning wheel was then replaced by a custom machined cast iron nut to which an 8 inch pitch diameter cast iron worm gear was mounted. The worm gear was driven by a mating worm directly coupled to 1 hp, 24 Vdc 1950 RPM compound wound motor. Since the gear train reduction ratio was 32:1 the worm gear was thus rotated at 1950/32 = 60.9 RPM thus closely approximating the design rate of 60 RPM. Details of the modified gate with its worm gear drive (Emerson 1972) are shown in Fig. 4.

CONTROL SYSTEM

The motor was rewired to allow operating in both directions. In the initial configuration the power to the motor was controlled by means of starting, contactor and reversing relays. These were later replaced by solid-state silicon controlled rectifier (SCR) switches (General Electric 1967) to avoid relay contact problems. The SCR's were mounted on a panel, along with the necessary timing and control circuits. Since the control circuits were continuously powered, conventional devices would have imposed too great a drain on the batteries. To avoid this problem, low-power IC devices were used.

To control the raising and lowering cycles of the gate a small battery operated clock which runs for a year on one "C" cell was used. A permanent magnet was mounted on the hour hand and two miniature reed switches on the clock face at the required operating times, 12:00 and 4:00 o'clock.

The sequence of systems operation (Fig. 5) is as follows:

When the modified clock (A) enables either the 'up' or 'down' reed switch, the closure sets or resets the debounce buffer (B) and the corresponding divide-by-two counter (C) or (D). The clock cycle is thus changed from 12 to 24 hours. For an 'up' sequence, active counter (C) will trigger transistor driver circuits (E) and (I). Driver (E) enables the 'up' pair of SCR's (G) while driver (I) latches the contactor SCR (K). SCR's (G) connect the leads of motor (M) to +24 V and to ground through SCR (K) and a current sensing resistor. Similarly, for a clocked 'down' sequence, (D), (F) and (I) latch SCR's (H) and (K), connecting motor (M) to +24 V and ground for reverse operation.

To test the lift gate between normal clock initiated cycles, external push buttons are connected in parallel with the clock switches. If the gate is left in a position not corresponding to the next clock trigger signal, operation in the wrong direction is prevented by interlocking with limit switch circuitry. The correct timing sequence will be restored on the next cycle.

Upper and lower magnet limit switches (N) and (O) are opened by a magnet on the gate's lifting shaft to turn the motor off at either end of the gate's travel. When opened, the switches trigger transistor driver circuit (J), momentarily pulsing turn-off SCR (L) which does not latch because of its 1000Ω load resistor (U). The negative going pulse at the anode of (L) is coupled through capacitor (V) to the anode of contactor SCR (K), switching off (K) and the motor, as well as removing the latched motor-switching SCR's from ground. The SCRs and motor are operated from the 24 V battery pack (S) which also supplies power to a 6 V voltage regulator for logic circuitry.

SAFETY AND OVERLOAD FEATURES

The motor current through sensor resistor (T) develops a voltage which is applied to an input of comparator (P). An adjustable reference voltage applied to the second input is set just above the 'trip' point of (P) under normal motor operation. In the event of failure of the limit switches to shut off the motor at the end of the gate's travel, the stainless steel screwed shaft is fitted top and bottom with stop collars to limit the gate travel. If the gate should jam, the motor current will quickly rise and the increased voltage across resistor (T) will trip (P), whose output is applied to driver (J) and time delay circuit (Q). Driver (J) triggers turn-off SCR (L) to shut off the motor; after two seconds, delay circuit (Q) applies a signal through directional gating circuit (R) to pulse the inactive circuitry as determined by the state of buffer (B). Either (E) and (G) or (F) and (H) will be triggered, as well as the contractor SCR (K), to reverse the motor, and the gate will be driven in the opposite direction.

If the gate jams completely during its travel, the increase in motor current will continually trigger overload comparator (P) which stops the motor and attempts a restart every two seconds. A 20 A "slo-blo" fuse in the main power line will blow after approximately 10 restart attempts thus preventing damage to the motor and draining of the batteries.

TESTING AND FIELD INSTALLATION

Following construction and pilot plant testing at the Freshwater Institute in Winnipeg the unit was transported on July 26, 1977, to Pacheta Lake, Manitoba, on the west side of Lake Winnipegosis. The batteries in their water proof container, were buried in the ground, the gate was attached to the culvert, and the interconnecting power cable installed. After checking for proper operation, the 10 gauge cadmium plated steel housing was bolted over the motor and controls. Then the earthen berm downstream of the gate was removed. Figure 6 shows the final installation looking downstream. With the control housing bolted in place and the system operating normally, the gate was considered secure from vandalism. Figure 7, with the housing lifted, shows the 1 hp motor and worm with the gate in the raised position. Looking downstream, Fig. 8 shows the control card and clock mechanism on the right and the large 8" worm gear on the left.

RESULTS

Since the final operating regime was determined to be 42 d maximum rather than the originally estimated 180 d, the system was operated automatically for this period of time. The gate performed satisfactorily except for two occasions when control system malfunction caused the gate to operate at the wrong times. A problem with sticking reversing solenoids had also been encountered in the pilot plant tests although this did not recur in the field trials.

To overcome the control system malfunction, the electronic circuit was redesigned to incorporate safety interlock hold-off circuits on the control card so that after the top or bottom limit switches are activated at the end of a cycle, a false trigger in the control system cannot cause the gate to move in the wrong direction. This prevents jamming of the stop collars and blowing of the main fuse. All solenoids were replaced with the solid-state SCR switching system mentioned earlier, to improve reliability and eliminate the possibility of sticking solenoids. The modified control system underwent pilot plant tests and was reinstalled on the gate.

Since the final operating regime was only 42 d rather than 180 d, the original 8 battery power pack was replaced with 2 heavy duty standard 12 volt, 110 Ah tractor batteries in series. A further field test of 42 d proved that the two batteries had sufficient capacity to operate the gate without recharging. The unit performed as expected with no malfunctions during the entire test period. Even if recharging was necessary during the season this could be easily done on site since the problems involved with recharging a parallel battery system would be avoided. Since this new battery system has proven satisfactory, considerable savings in battery pack cost have been demonstrated. The reduction of batteries over the original design reduced the cost per installation by about $300 as well as cut down considerably on the size and weight.

Final cost of the installation including both sets of batteries and both solenoid and SCR switching systems was $1108, or just slightly higher than the original estimate of $1100.

FUTURE MODIFICATIONS AND TESTS

Phase II will consist of fitting a hydraulic operating mechanism to a 30 inch gate and installing the gate on another rearing pond control channel. The electronic control system will be similar to that for the mechanical system but will be somewhat simplified since motor reversal will not be required. The method will, instead, employ a 4-way hydraulic solenoid valve to divert the flow of hydraulic fluid to ports at opposite ends of a double-acting hydraulic cylinder.

Also, the housing over the motor and controls will be only seven inches high compared to 32 inches for the mechanical system, since it will not have to accommodate the rising screw shaft. Following tests, a comparison will be made of the relative merits of the mechanical versus the hydraulic system. A separate report will be prepared on this alternate system.

ACKNOWLEDGMENTS

I thank Trevor Smith and Hugh Valiant of the Department of Renewable Resources, Province of Manitoba who provided the original gate for modification and did the site preparation for, and installation of, the modified automatic lift-gate. Henry Ballon, of the Freshwater Institute, designed and constructed the electronic control system.

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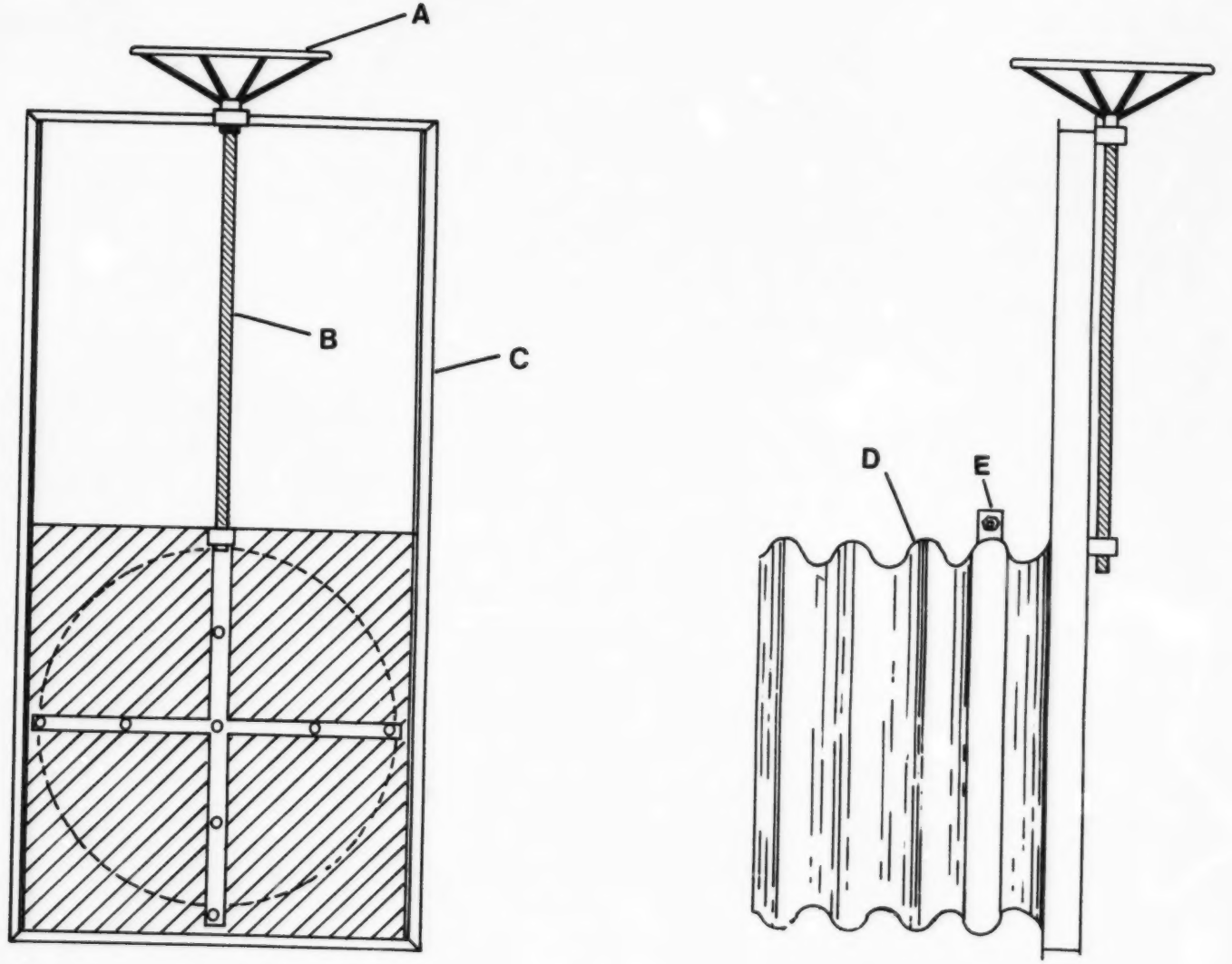

Fig. 1. Manually operated control gate - A, hand wheel; B, threaded shaft; C, gate upright supports; D. channel culvert; E, lift-gate culvert coupler.

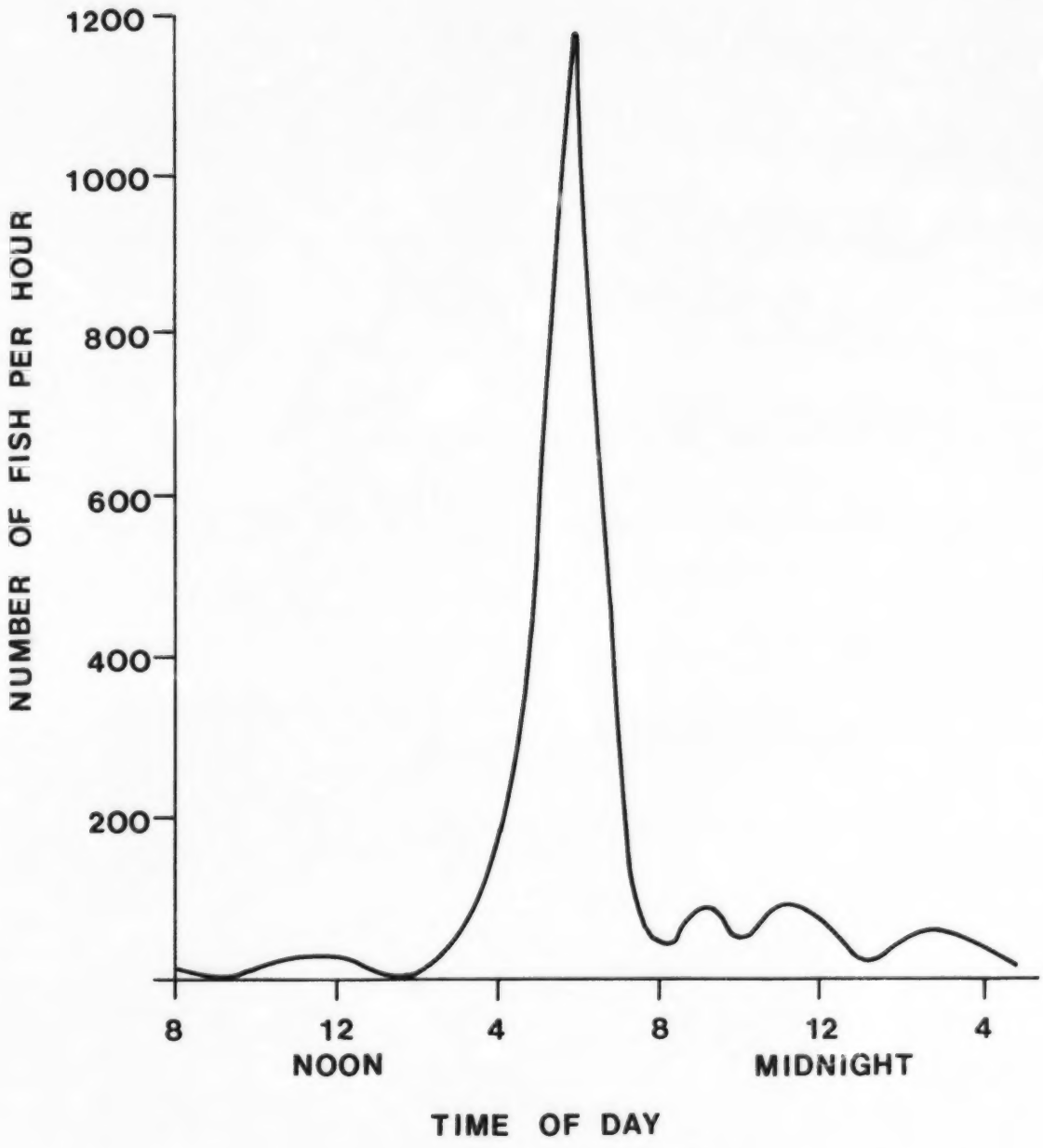

Fig. 2. Walleye migration pattern.

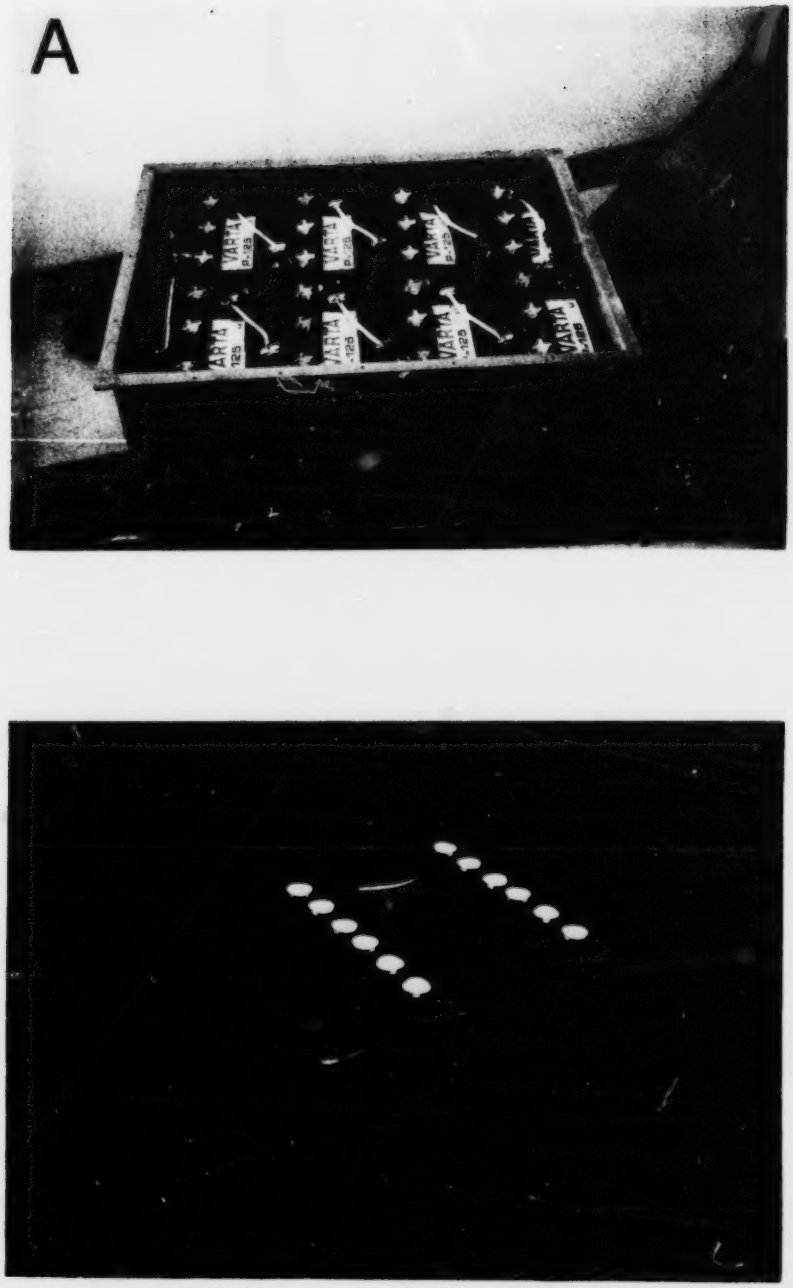

Fig. 3. Battery power pack in waterproof box.
A. Original configuration (cover removed)
B. Final configuration (cover removed).

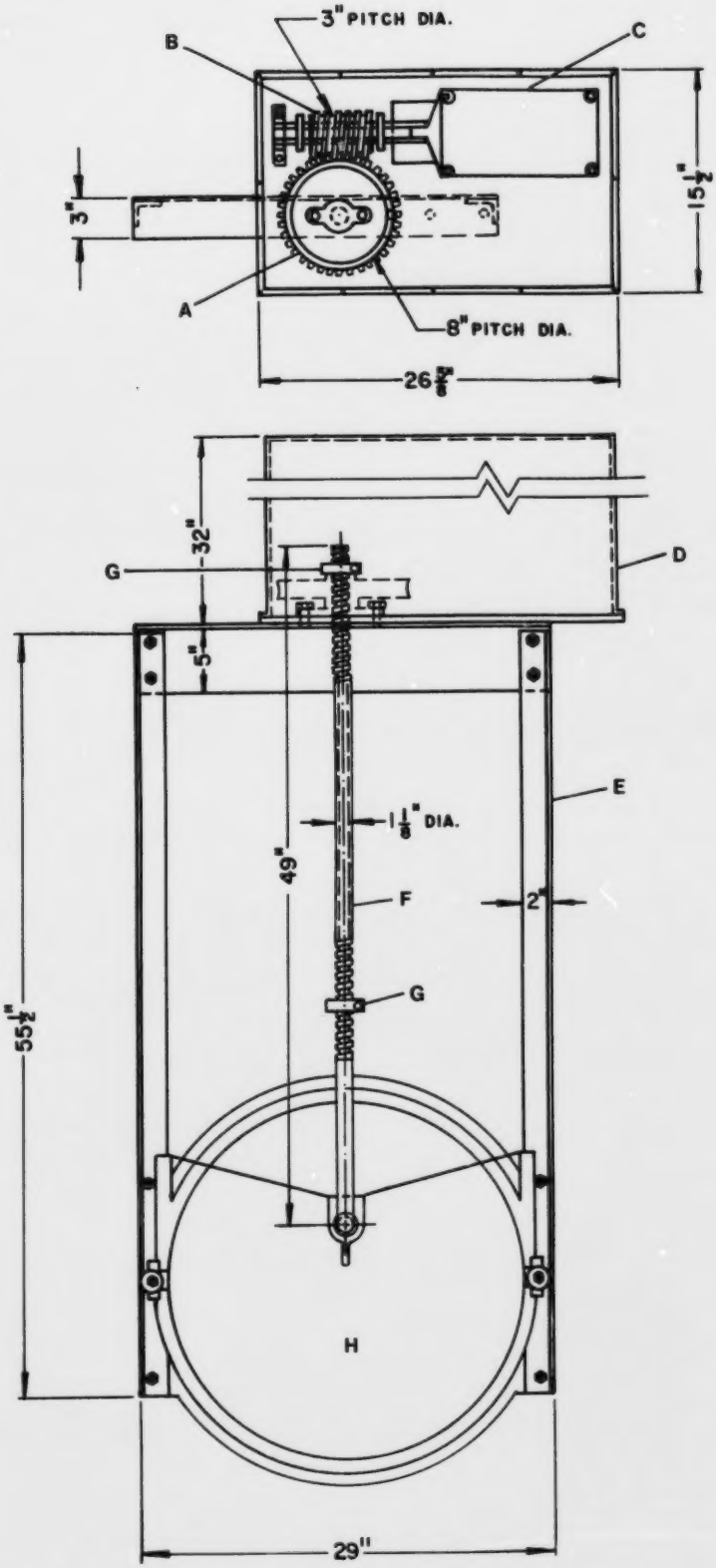

Fig. 4. Modified gate details - A, Browning worm gear CWG 432-1 cast iron; B, Browning worm W4A-1 steel; C, Motor 1 hp 24 Vdc compound wound; D, Control compartment housing, E, 2" x 2" gate upright supports; F, 1 1/8" diameter stainless steel threaded shaft; G, top & bottom stop collars.

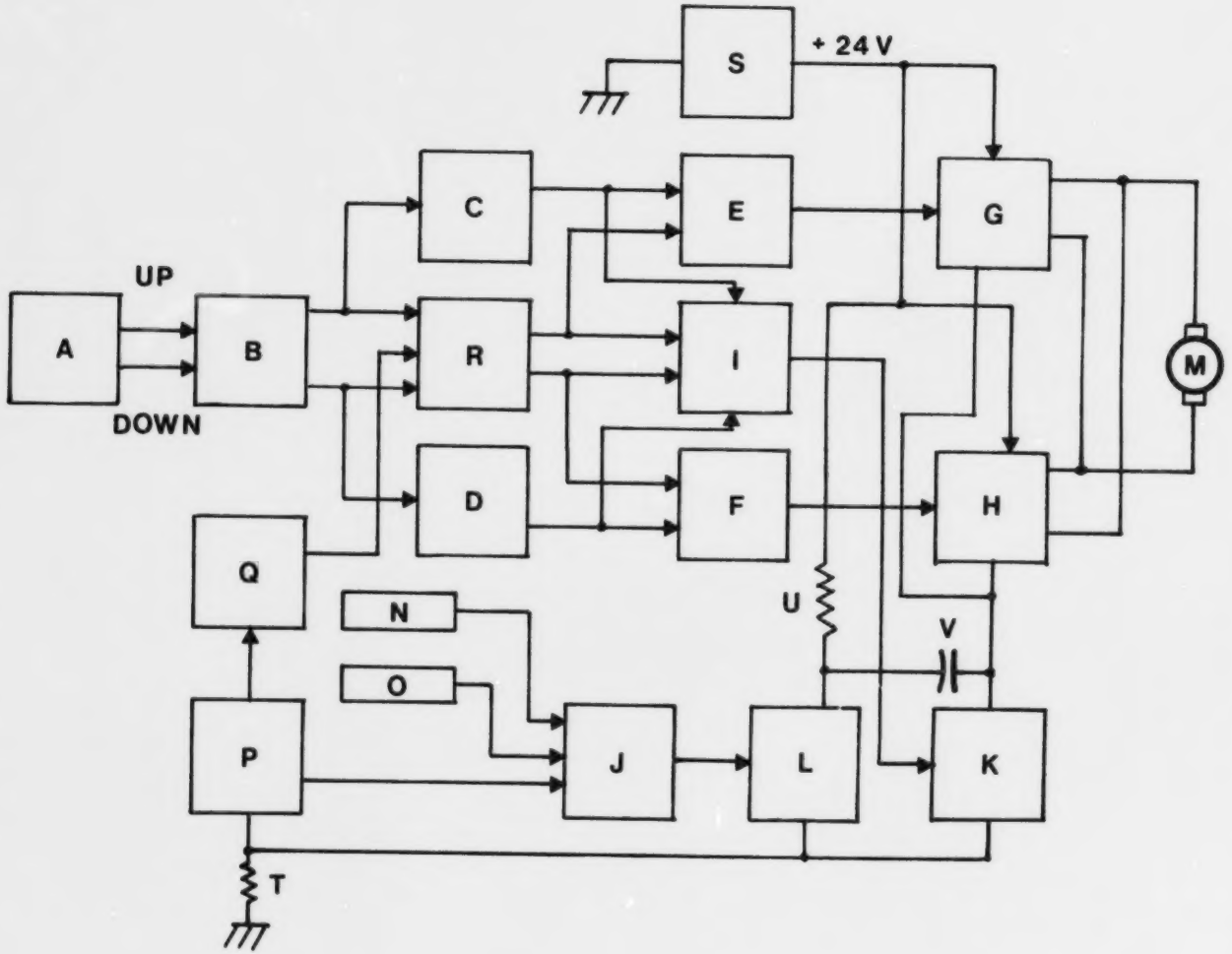

Fig. 5. Control system block diagram - A, clock; B, debounce buffer; C, D, ÷ 2 counters; E, F, 'up' and 'down' transistor driver circuits; G, H, 'up' and 'down' SCR switching pairs; I, contactor transistor drive circuit; J, turn-off transistor drive circuit; K, contactor SCR; L, turn-off SCR; M, 24 Vdc motor; N, O, upper & lower limit switches; P, overload comparator; Q, time delay circuit; R, directional gate; S, 24 Vdc battery pack; T, 2.4 m Ω current sensor resistor; U, 1000 Ω load resistor; V, 3000 μF coupling capacitor.

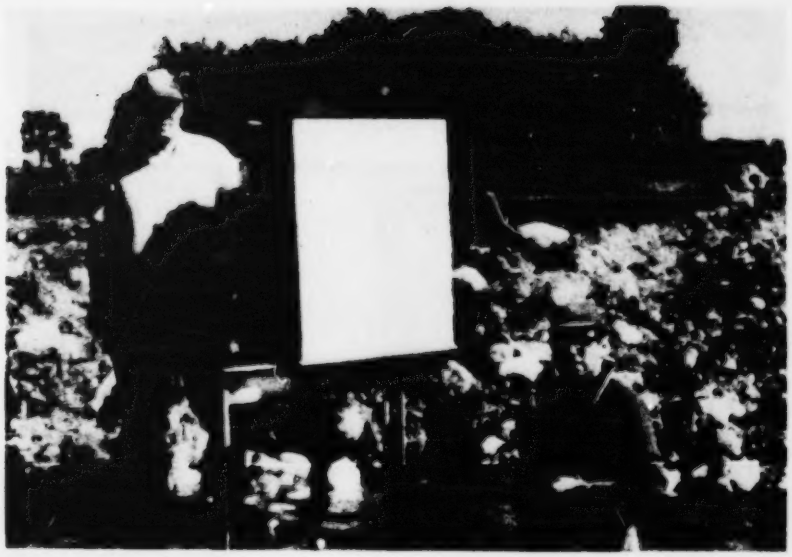

Fig. 6. Pacheta Lake unit (normal operating mode).

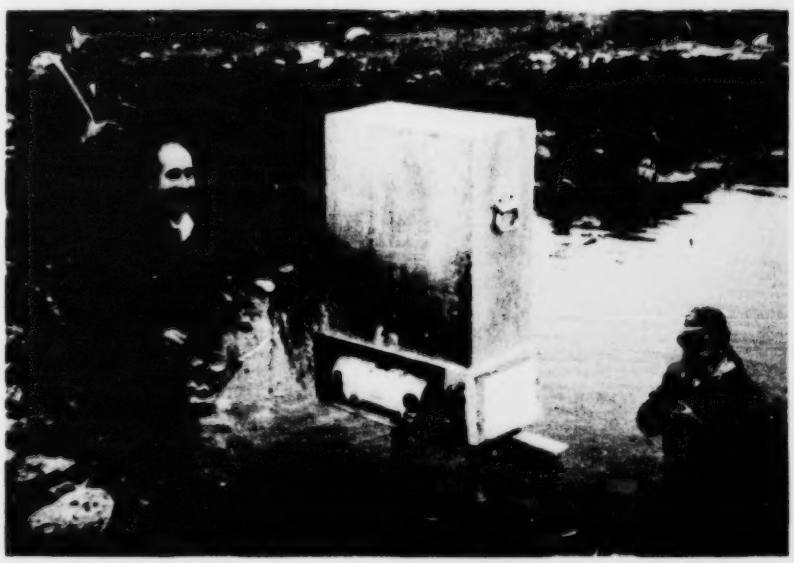

Fig. 7. Pacheta Lake unit (housing lifted).

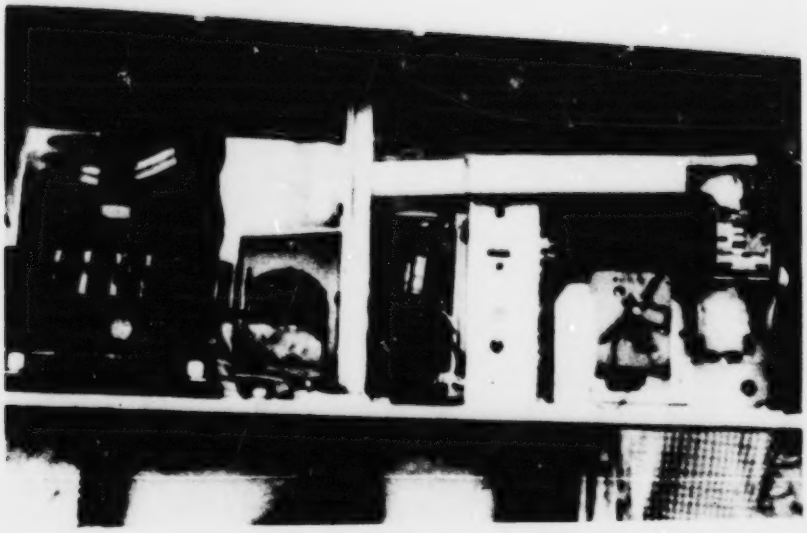

Fig. 8. Pacheta Lake unit (showing controls and worm gear).

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